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Effects of Recreation on Water Quality in Wildlands

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by

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INTRODUCTION

Are concentrations of campers in wildland areas contributing to water pollution? Does the water pollution load increase as user concentration increases? Do different types of users and different types of access have different influences on the pollution load? If so, how much and what types of water pollution result from the individuals who are utilizing the wildland areas for the purposes of recreation. Answers to these questions have definite management implications for the protection of the resource and the health of the users.

Present day society is demanding more and more opportunities for outdoor recreation plus high levels of environmental quality. The problems of supplying these elements are intensifying. Thus, the following study is designed to answer the above questions in order to provide the manager in the field with a foundation from which to work in overseeing the administration of wildland campsites to maximize outdoor recreation opportunities while still maintaining an acceptable level of water quality.

Background

Past and present information indicates that there is likely to be an ever-increasing demand for outdoor recreational opportunities in the future. A prediction made in the early 1960s by the Outdoor Recreation Resources Review Commission stated that recreational activities in the United States could as much as triple from 1965 levels by the year 2000. This situation is promulgated by the synergistic effect of such demographic factors as increasing population, income, leisure time, and individual mobility in addition to such socio-psychological variables as the return-to-nature mentality, the need to escape the workaday world, etc.

Water is a focal point of outdoor recreation. In 1968, the Water Resources Council (1968:4-6-1) reported: "About one-fourth of all outdoor recreation is and will continue to be dependent upon water." Just five years later, the National Water Commission (1973) stated that about one-half of all outdoor recreation activity is in some way associated with water. These water-oriented outdoor recreation activities include: fishing, boating, swimming, waterskiing, picnicking, camping, and many other related activities. Clearly, water is of great value as a recreational resource.

However, the utilization of a water body for outdoor recreation has given rise to a number of apprehensions concerning the impact of recreational use upon water quality. William Bullard (1963:314), in a speech to the Forest Watershed Management Symposium in Corvallis, Oregon, verbalized this concern as it pertains to wildland recreation:

> ...a problem that is developing everywhere, and which in places is becoming intolerable, is that of pollution arising from recreational use. Most recreation in wildlands is associated with water, and most recreation areas are located along streams and lakes. Sewage and garbage disposal present problems almost of urban proportions, and disposal occurs high in the watershed near stream

sources and above other water uses.

The greatest emphasis in water quality ontrol has been placed in the areas of domestic, ndustrial, and agricultural water pollution, ince these are usually the sources of grossest nd most widespread water pollution. Rela- vely little attention has been paid to other ind uses and their effect upon water quality.)ne of these "other" land uses is wildland ecreation, and despite claims to the contrary, ttle is actually known about the impact upon ildland water quality due to recreational use.

A knowledge of the impact of recreational se upon water quality is important for at east three reasons. First, it appears that ie quality of wildland water cannot be dimin- shed without a concomitant reduction in the uality of the wildland recreation experience. econd, increasing recreational use may in- rease the potential health hazards for recrea- onists. Third, there is a potential pollution sk to other water users which needs arification.

Objectives

The basic purpose of this study is to onitor and evaluate the effect of present oncentrations and varying types of campers oon wildland water quality. This is re- iired to determine the amounts and types water pollution present and to ascertain hether water quality standards are being et. The data can then be used to suggest anagement alternatives (i.e., to derive ossibilities for increased or, if need be, ecreased utilization of certain campgrounds). ecause levels of use and the accompanying roblem of waste generation are a function access, particularly in remote and less eveloped areas, it is important to know the imber, quality, and location of access outes. Thus, the overall objective of this esearch is to make recommendations for or gainst recreation distribution systems (roads d foot paths) which allow access to campsites which a neutral or a negative impact upon ater quality is found to be associated with rticular concentrations and/or types of ampers. Other related management meas- res, such as available toilet facilities, log rriers, etc., will also be discussed.

This study had three primary objectives. These are listed below:

Objective 1: To determine if bacterial densities increase in water as recreational-user (campers) concentrations increase in nearby campgrounds.

Objective 2: To determine if there is a significant difference between the water-quality impact imparted by motorized campers and the water-quality impact imparted by backpack campers.

Objective 3: To determine if there are significant differences between the water-quality impacts occurring in campgrounds accessible by means of paved roads, unpaved roads, and foot paths.

Definitions

For the purposes of this study, water-quality impact is the type of bacterial variation that occurs within a given campground. There may be no change in the bacterial counts, or there may be an increase or a decrease in the bacterial counts. The primary concerns of this study are the number of water-quality observations in which an increase in bacterial concentrations occurs and the magnitude of those increases at the lower sampling station. Recreational-user concentrations denote the number of campers per acre of available campground. The scaling for camper concentration is low, moderate and high concentrations. Camper types included in this study are: motorized campers which are car campers, camper-trailer users, Winnebago-type campers; and backpack campers who hike into the campsites. The recreation distribution systems considered in this study are: paved roads, unpaved (dirt or gravel) roads, and foot paths.

LITERATURE REVIEW

A study of the results of two separate areas of research was required before undertaking this study. The review of literature examines both of these areas. First, there is the use of fecal coliform and fecal streptococci bacteria as pollution-indicating organisms. Second, previous work concerned with the effect of recreational activity upon water quality created a starting point for this study and provided complementary information about the efficacy of utilizing certain bacterial groups as indicators of recreational impact upon water quality.

Fecal Coliform and Fecal Streptococci Bacteria

In recent years, fecal coliform and fecal streptococci bacteria have gained acceptance as indicators of fecal pollution. These bacteria occur in the intestinal tract of man and all other warm-blooded animals and are eliminated in large numbers during defacation. Geldreich (1966, 1970, 1972) and Kunkle (1965) have pointed out that the presence of these bacteria in water can be accepted as proof of fecal contamination by warm-blooded animals including man.

Fecal coliform and fecal streptococci bacteria, although not pathogenic themselves, indicate by their presence that pathogenic micro-organisms may occur in the water. Geldreich (1972) states that the feces of man and other warm-blooded animals are a major source of pathogenic micro-organisms. Thus, fecal coliforms and fecal streptococci are of significance in evaluating the potential health hazard of a water body.

However, fluctuations in the concentrations of these bacteria may be related to a number of factors. Kunkle and Meiman (1967) investigated the relationship between bacteria and certain natural phenomena such as streamflow, turbidity, suspended sediment, and pH. They found that fecal coliforms and fecal streptococci were positively related to streamflow, suspended sediment, and turbidity; they were negatively related to pH.

Later, Kunkle and Meiman (1968) undertook a more extensive study of bacterial variations, this time to define the temporal fluctuations in bacterial numbers. They found both daily and seasonal variations in the numbers of these bacteria in water. They concluded that daily variations in bacterial concentrations may be associated with stream stage, water temperature, and/or insolation effect. The highest bacterial counts occurred during the evening hours, while the afternoon counts were the lowest, and morning counts fell somewhere in between. Seasonal variations differed for "natural" and "used" areas. In this case, a "used" area was defined as a pasture grazed by cattle. The "natural" or unused area exhibited a "post-flush" rise in bacterial numbers, while the "used" area showed a bacterial rise during the flushing period associated with spring snowmelt.

Thus, Kunkle and Meiman (1968:25) concluded: "Land use impact on stream water quality appears to be most drastic during periods of stream rises ('flushing') associat with snowmelt runoff and storm rises in the hydrograph." This action of runoff "flushing adjacent land areas during storms and snowmelt had been previously described by Morrison and Fair (1966:20) who pointed out that: "Addition of bacteria to the stream fro land surfaces of the watershed during short-duration summer rainstorms is the most important cause of variation in bacterial numbers in the stream studied."

Kunkle (1970) again addressed the phenomenon of surface flushing caused by overland flow of water by pointing out that overland flow probably takes place most often near the stream where the nearby soil is already saturated with moisture. Bacteria in the absence of overland flow or "surface flushing" will not travel far in the soil. In dry or only slightly moist soils, bacteria m not travel more than a few yards (Butler, Orlob and McGauhey 1954). Thus, bacteri sources (feces) must occur near the water body rather than in upland areas. In an attempt to relate censuses of humans or animals to an impact upon water quality, Kunkle (1970:130) stated that "water quality interpretations must be based on considerat of proximity of particular activities to the stream channels, the specific hydrologic conditions and processes involved, and othe factors."

Water Quality and Recreational Use

The major controversy over recreation use of water is based upon a sanitary conce Thomas D. McKewen (1966:1270), a Maryla Public Health Engineer, has said: "In a discussion of recreational use of watershed the stage is set for a debate between advoca of increased recreational facilities and thos individuals who are responsible for protecti the public water supply." Thus, a greater portion of the investigations concerned with water-based recreation and water quality have dealt with this problem. The parameters measured in most of these studies have been bacteria of sanitary significance, e.g., fecal coliforms, fecal streptococci, and total coliforms.

Carswell, Symons and Robeck (1969) put together a partial review of studies dealing with water quality and recreational use. The authors cited five "completed" studies that seem to indicate that little or no impairment of water quality occurs due to recreational use (California Dept. of Public Health, 1961; Roseberry, 1964; Karalekas and Lynch, 1965; Minkus, 1965; and HEW, 1966). However, Carswell, Symons and Robeck (1969:303) stated that these investigations suffered a number of shortcomings:

> No control was included in many of them. Most of the studies were done when measurement of total coliform density was the only bacteriological pollution indicator system available. Further, the studies were done before adequate methods for assaying bacterial and viral-pathogen content of the water were available.

Dutka (1973:39) has pointed out a number of reasons why the use of total coliforms as a sanitary index of water quality is a meaningless endeavor:

> The rejection of coliforms as indicator organisms is based on criteria of the true indicator system. To conform to these criteria, indicator organisms should:
>
> (1) be present and occur in much greater numbers than the pathogens concerned;
>
> (2) not be able to proliferate to any greater extent that (sic) enteric pathogens in the aqueous environment;
>
> (3) be more resistant to disinfectants and to the aqueous environment than the pathogens;
>
> (4) yield characteristic and simple reactions enabling as far as possible an unambiguous identification of the group.
>
> In the past 10 years, various researchers, as well as studies initiated in our laboratory, have shown that coliforms do not fulfill any of the above criteria.

Other investigations have supported the argument that recreational use has no significant adverse impact upon water quality. Walter and Bottman (1967) compared the microbiological and chemical water quality of a closed watershed and a watershed open to recreational use. They found that bacterial counts (fecal coliforms and fecal streptococci) were higher for the closed watershed than for the watershed open to recreation. At the time, the investigators could not adequately explain this result. However, Stuart et al. (1971) further studied the closed watershed, which in 1970 had been opened for "limited recreation and logging." They found that bacterial contamination had decreased in the streams of the watershed after it had been made available for human use. These individuals concluded that "...these human activities drove from the watershed a large wild animal population which had contributed substantially to the previous bacterial pollution" (Stuart et al., 1971:1048).

Skinner et al. (1974) studied the bacterial water quality of a Wyoming watershed open for recreation and livestock grazing. "Recreation within the study area includes public campgrounds, picnic areas fishing access roads and areas, cabins, and a public ski area having a carrying capacity of approximately 1,000 skiers per day" (Skinner et al., 1974:329). These individuals found that bacterial counts (fecal coliforms and fecal streptococci) were generally low, frequently much lower than the monthly mean of 200 organisms/100 ml. suggested by Geldreich (1970) as the highest acceptable concentration level for fecal coliform bacteria in recreational waters.

Moreover, this particular study also included a water quality monitoring effort on a sub-watershed designated as "natural" and open only to hikers and wildlife. The investigators found that the yearly mean for fecal coliforms in 1970, 1971 and 1972 were 1.2, 0.6, and 0.2 organisms/100 ml. respectively. For the fecal streptococci bacteria, the means for the same years were 22, 2, and 3 organisms/100 ml. respectively. The hikers probably had little or no adverse effect upon the water quality of the sub-watershed.

Other investigators have found that recreational utilization of water may have caused an increase in bacterial counts. Thus, Wagenet and Lawrence (1974) studied bacterial counts (fecal coliforms) of Lake Thunderbird in Oklahoma, a domestic water supply reservoir open to recreational use. In this case, the investigators found that there was a correlation between high recreational use and a rise in bacterial counts, hence, a decrease in water quality levels. However, in monitoring bacterial water quality at the intake tower, where water is withdrawn from the reservoir for treatment and domestic use, it was found that bacterial counts were generally low. Thus, the rise in bacterial concentrations was localized in the areas of high recreational use, and, given the dynamics of bacterial populations and the ability of a water body to "cleanse" itself over time, there was no significant decrease in the quality of the water eventually withdrawn for domestic use. The authors concluded that: "These findings support the position that reservoirs can be used jointly for water supply and for recreational use" (Wagenet and Lawrence 1974:20).

Dietrich and Mulamoottil (1974) compared the "intensity of recreational use to deterioration in water quality." Their conclusion was that recreational activity on a reservoir in Canada did result in increased bacterial concentrations (fecal coliforms and total coliforms). However, the authors admitted that their research was not conclusive. Dietrich and Mulamoottil (1974:17) added that "Much more intensive sampling frequency is needed to substantiate this apparent relationship."

Johnson (1975) carried out research on recreational use and water quality impact for a watershed in Utah's Wasatch Range and concluded that there appeared to be a relationship between the total number of people visiting a recreation area and an increase in total coliform bacteria. Johnson suspected that faulty toilets were the cause of some of these increases, and he thought that user behavior and length of stay were also factors contributing to the bacterial increases in the water near the campgrounds. "It may be possible that short term visitors have a greater impact on water quality because they use toilet facilities with more frequency or care less about taking care of recreational facilities than long term visitors" (Johnson, 1975:90).

Thus there is a divergence of opinion the question of recreational impact upon bacterial water quality levels. Given the prediction of greater demand for water-ba recreation, research must continue in an attempt to resolve the controversy. This study adds to the body of knowledge and sh help in resolving the controversy.

There is a need to know the type and quantity of water pollution being generate within wildland campgrounds; it is also important to control the influence of othe water and land uses on water quality. Th pretest-post test research design used in study (see Research Design and Methods) an attempt to isolate and define just such impact for campgrounds. Since fecal col and fecal streptococci are good pollution-indicating organisms, their use aids in th endeavor. Johnson (1975) and others hav found that these bacteria are more sensit indicators of recreational pollution than a chemical and physical parameters such a nitrates, chlorides, dissolved oxygen, et Water temperature, streamflow, the cam ground's proximity to water, weather, a temporal variables are considered in the interpretation of bacterial variations wit the campgrounds. The number and varie of campgrounds included in this study an number of samples taken adds to the reli bility and validity of the resulting data.

The present study compares the wate quality impact of two types of campers-- motorized campers and backpack camper which are probably the two largest recre ational-user groups utilizing America's wildlands. Consideration of backpack ca does not occur in the literature, except f the "hikers" included in the work of Skin et al. (1974). The comparison of these backpack campers and motorized campe to their respective effects upon water qu and the comparison of user concentratio to water quality impact is of value in the formulation of management plans.

The concept of a carrying capacity a available sanitary facilities has been dea with, at least implicitly, in some of the previous studies of recreational use and water quality impact. However, conside of particular access routes as management tools has not been evident. The present research is of added value, since it deals at length with this factor (recreation distribution systems), as well as carrying capacity and available sanitary facilities.

This study strives to utilize the factors discussed above in order to provide information that may be useful to managers in the field in determining opportunities and methods for expanding or restricting recreational use of wildland watersheds. The primary goal of such research, from the standpoint of the recreation field, is to provide maximum recreational opportunities while maintaining an acceptable level of environmental quality.

RESEARCH DESIGN AND METHODS

Study Area

Campgrounds were chosen as data collection sites since most concentrations of wildland users occur in such locales. The eight campgrounds chosen for study are located in the Colorado Front Range west of Fort Collins, Colorado. These campgrounds were chosen because they embody the characteristics sought in this research: they are all heavily-used campgrounds; they are all located along water; they are accessible by different types of access routes; and they cater to different types of campers. Each campground included in this study is served by one of three types of recreation distribution systems: a paved road; an unpaved road; or a foot path (see Figure 1). The former two distribution systems allow access to motorized campers, and the latter distribution system allows access to backpack campers. This is a representative population of the types of campers using the study area and most other wildland recreation areas.

The Cache la Poudre River constitutes the major water-based recreational resource in the area. The Cache la Poudre, a tributary of the South Platte River, drains a total area of 1,055 square miles. The small communities of Rustic and Poudre Park are the only population centers along the main stem of the river above the mouth of the Poudre Canyon. There are also a number of second-home developments and a fish hatchery located on the main stem of the river. Morrison and Fair (1966:4) point out that "... numerous improved picnic and camping areas on the stream contribute much to the population density during the summer." Summer recreational use of the area is extremely high, and on many days, particularly weekends, the campgrounds along the river are filled to capacity.

The two major tributaries of the Cache la Poudre River are the North and Little South Forks of the Cache la Poudre River. The Little South Fork (Little South Poudre) catchment covers approximately 105 square miles in Larimer County, Colorado and ranges in elevation from 6,550 feet above sea level where it joins the main stem of the Cache la Poudre River to about 13,400 feet above sea level at the top of Rowe Peak. The average elevation of the Little South Poudre watershed is 9,700 feet (Mercer, 1966). The watershed is characterized by alpine, subalpine and montane life zones, and the primary tree species is lodgepole pine with some spruce-fir, ponderosa pine, aspen and meadow grasslands. The mean annual precipitation in the Little South Poudre watershed is estimated to be between 18 and 20 inches (Johnson, 1962). Meiman and Leavesley (1974) found the mean annual precipitation at Pingree Park to be 21.11 inches between 1963 and 1971. About 40 percent of the total annual precipitation falls as snow during the winter months and appears as runoff with the rising temperatures of late May and early June. The typical falling hydrograph of the summer months is periodically interrupted by rainshower runoff in July and August. "From October through May flow is low and steady" (Mercer, 1966: 31).

Land utilization within the Little South Poudre watershed includes Pingree Park Summer Camp of Colorado State University, summer homes, campgrounds and picnic areas, some logging activity, ranching, and livestock grazing.

The watershed is made accessible primarily by means of the Crown Point/Pingree Park road system (unpaved) and various lesser access roads which are open during the summer months. Browns and Comanche Lakes, located at the headwaters of Beaver Creek which is a tributary of the Little South Fork, are accessible by a system of foot paths.

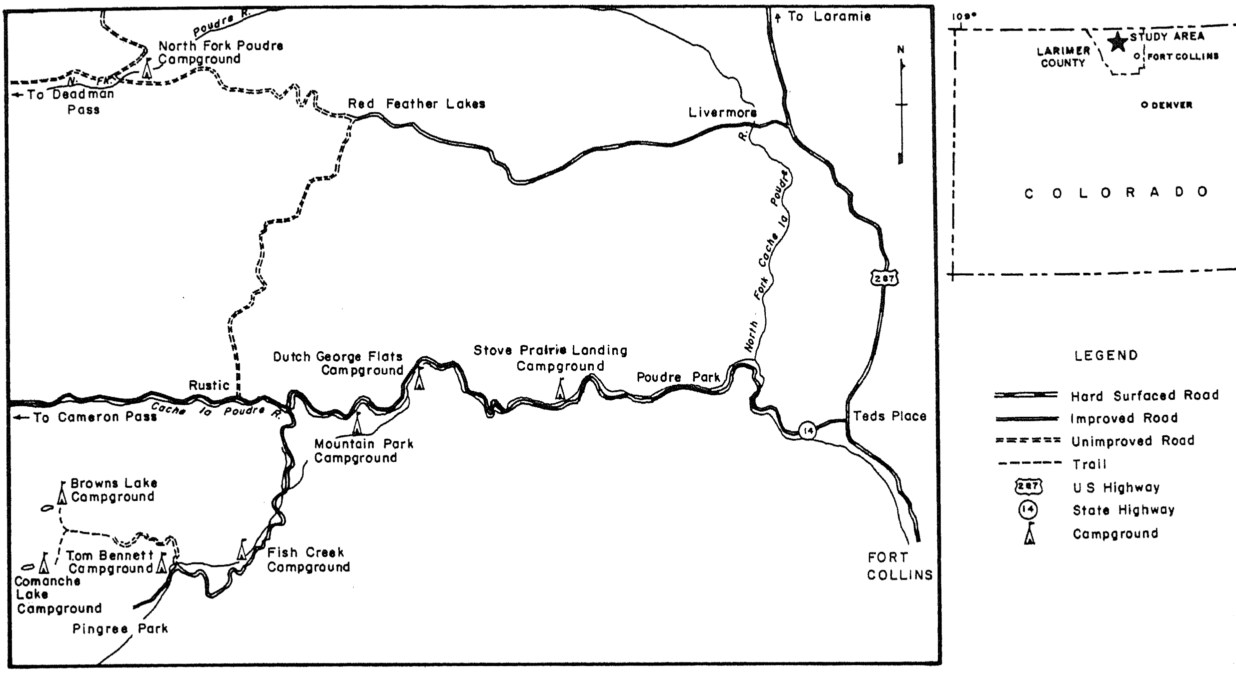

Figure 1. Study area map showing campground locations and access.

The North Fork of the Cache la Poudre River (North Poudre) drains an area of approximately 466 square miles in Larimer County, Colorado. The watershed ranges in elevation from 5,400 feet above sea level at the junction of the North Fork with the main stem of the Cache la Poudre River to 11,004 feet above sea level at the summit of Bald Mountain. The mean elevation of the watershed is 7,788 feet. The area is primarily covered with lodgepole pine, spruce-fir and ponderosa pine with some aspen groves, sagebrush flats and meadow grasslands. Black et al. (1959) estimated that annual precipitation on the watershed was about sixteen inches, although the local topography makes the amount variable over the entire watershed. As much as 70 percent of this precipitation falls as snow during the winter.

Land use within the North Poudre watershed includes the small communities of Redfeather and Virginia Dale, summer home developments, ranching, livestock grazing, campgrounds and picnic areas, youth camps, and some logging activity. The primary access route into the watershed is via the Redfeather Lakes Road (partially paved) and a system of unpaved access roads.

Three of the campgrounds included in the present research are located along the m stem of the Cache la Poudre River. The campgrounds are Stove Prairie Landing, Dutch George Flats, and Mountain Park. three of these campgrounds are accessibl by means of Colorado Highway 14. Moun Park and Stove Prairie Landing are unde the jurisdiction of the Poudre District of Roosevelt National Forest and are provid with vault-type toilet facilities and trash Stove Prairie Landing Campground (3.5 a has approximately nine parking spaces p vided and log barricades prohibit direct vehicular access to the river. Mountain Campground (31 acres) has approximatel twenty-eight camping spots and sixty-six picnic units. Log barricades again prohi approach to the river. This campground has potable water available. Dutch Geor Flats Campground (12 acres) is located o parcel of private land within the national forest; no toilet facilities or trash cans a provided at this particular campground. Moreover, this campground does not hav barricades preventing vehicular access t the river.

Four additional campgrounds are loc within the Little South Poudre watershed; these are also under the jurisdiction of t Poudre District of the Roosevelt National

rest. Tom Bennett and Fish Creek Camp-
ounds are accessible via the Pingree Park
ad (unpaved), and these campgrounds have
ult-type toilet facilities and trash cans
ovided. Tom Bennett Campground (5 acres)
s approximately seven designated camping
ots with log barricades, but campers crowd
o this campground and utilize other, un-
signated areas within the campground for
mpsites. Fish Creek Campground (6 acres)
actually a string of pullout camping spots
h a number of designated campsites (log
rricades present) and undesignated camp-
es (log barriers absent). This series of
llouts is located downstream from Fish
eek Picnic Ground. The remaining two
mping areas within the Little South Poudre
tershed are located at Browns Lake and
manche Lake. These areas receive consid-
able use by backpack campers. Toilet
ilities are provided at Browns Lake but not
Comanche Lake.

The final campground included in this
dy is North Fork Poudre Campground (5
res) which is located within the North
udre watershed. This campground is under
jurisdiction of the Redfeather District of
osevelt National Forest. Vault-type toilet
ilities and trash cans are provided, and
re are nine camping spots provided with
barricades. This campground is acces-
le by means of Deadman Road (unpaved)
st of the Redfeather Lakes area.

Sampling

This study measures the impact of a
ecific land use--recreation--upon water
ality. The research design is of a pretest-
st test nature. In order to ascertain
ether a negative impact (bacterial increase)
s being imparted by recreational use of
mpgrounds, a sampling station was located
stream from each campground to determine
e water-quality level of the stream as it
tered the area of the campground. This
stream station served as the pretest or
ntrol. A second sampling station located
wnstream from each campground to monitor
ter quality of the stream as it left the area
the campground provided the post test. In
e cases of Browns Lake and Comanche Lake,
e upper sampling station was located on the
keshore well away from the areas of camper
congestion, and the lower sampling station was located on the lakeshore near where the campers set up their tents. This research design treats campgrounds as "point" sources of pollution. Seemingly, this approach is possible since, if one addresses the whole of the Cache la Poudre River watershed, the campgrounds become discrete points of potential pollution.

The upper and lower sampling stations were located so as to include within their limits all possible recreational activity associated with the campgrounds. The stations were also located so as to obtain representative results for the upper and lower sampling stations, that is, the upper and lower sampling stations were made as much alike as possible with respect to water depth, stream width, turbulence, etc.

Logistically, it was not possible to measure streamflow levels at each sampling station; therefore, the influence of such factors as dilution are unknown. This makes comparison between campgrounds along different streams difficult. However, differences between streamflows in different streams were obtained from existing streamflow records; from these a fair estimate of dilution factors have been obtained to compare water-quality results between campgrounds. The main vehicle for determining water-quality impact in this study is the change in bacterial counts between the upper and lower sampling stations of each campground, but differences in dilution factors are needed to interpret the results.

Sampling Period

The study was conducted from July 21, 1974 to July 20, 1975; one major runoff period was observed. During the summer of 1974, samples were collected twice weekly, while samples were taken monthly during October, November and December of 1974. Heavy snow accumulation then caused a halt in sampling until April of 1975, and from April, 1975 until July, 1975, samples were collected weekly. The exception to this is that heavy snows continued to prohibit access to Browns and Comanche Lakes until June of 1975.

Sampling Method

A half-liter polyethylene bottle was used to collect water for bacterial examination. Each sterilized bottle was thoroughly rinsed in the stream or lake before it was filled, and the samples were then transported on ice to the Colorado State University Microbiology Laboratory in Fort Collins for analysis. A second bottle of sample water was collected at each sampling station to determine dissolved-oxygen concentrations, nitrate concentrations, and turbidity. The Hach modified Winkler Method, discussed in *Standard Methods for the Examination of Water and Wastewater* (1971) was used to determine the dissolved-oxygen concentration. Nitrate concentrations and turbidity were also determined using the Hach Kit, and temperature was taken with a pocket centigrade thermometer. Further, direct headcounts of recreationists present in the campgrounds were taken at the time of water sampling.

Bacterial Analysis Techniques

The bacterial analysis was carried out using the membrane filter technique as described in *Standard Methods* (1971). Fecal coliform concentrations were determined using M-FC Broth with an incubation period of 24 hours at 44.5°C. Fecal streptococci bacteria concentrations were derived using M-Enterococcus Agar Medium and incubating at 35°C for 48 hours.

Visitor Survey

During the study period, a visitor questionnaire was randomly distributed to campers within the campgrounds. The main purpose of this survey was to determine certain characteristics of the individuals utilizing the campgrounds within the study area. Of particular interest were answers to questions concerning what the water in the area was used for by the campers, whether the campers used the facilities (toilets) provided within the campgrounds or whether the campers had self-contained vehicles, and how and where campers disposed of wastes generated during their stay at the campgrounds. The answers to these types of questions aid in interpretation of the biological findings of this study.

Data Analysis

A scaling mechanism was required in an attempt to correlate various parameters included in this study. Thus, the water-qualit parameters (bacteria) are scaled nominally according to the type of parameter change found. The concern was whether the bacteri indicators exhibited a decrease, an increase or no change at all between counts found at the upper sampling station and counts found at the lower sampling station of each campground. A decrease in bacterial numbers indicates that a certain amount of "purification" is taking place along the stream stretch, and no bacteria are probably being introduced from the campgrounds. No chan in bacterial counts between the upper and lo sampling stations would seem to indicate th some bacteria are being introduced from th campground. The reasoning is that, given the possibility of a reduction in bacterial counts between the upper and lower samplin stations due to dilution and natural cleansin to maintain the "status quo" with respect to bacterial counts some bacteria must be bei introduced from along the campground. It i not clear what the significance of this phen enon is to water-pollution levels, but it doe appear to be associated with a certain amo of water-quality impact. However, the ma interest of this study is to find readily mea urable increases in bacteria between the up and lower sampling stations and to determi the magnitude of these increases.

The other factors considered in this st are nominally scaled as follows:

Recreational-user types--motorized campers and backpack campers,

Recreation distribution systems--pave roads, unpaved roads, and foot paths,

Recreational-user concentrations (in a particular campground)--high, moderate, and low user concentrations.

A lambda correlation coefficient is us to identify associations between recreatio user concentrations and water-quality imp between recreation-user types and their impact upon water-quality levels, and betw recreation distribution systems and water quality impact. Chi squares are used as tests of significant differences between the

ter-quality impacts of the different camper
ncentrations, camper types, or campgrounds
cessible by means of the different recreation
tribution systems.

Stream Classification

The Cache la Poudre River watershed,
luding the Little South Poudre and North
udre sub-watersheds, upstream from the
nt of water diversion for Greeley's water
atment plant, has been classified as Quality
ass B_1. This classification, adopted pursuant
the Federal Water Pollution Control Act
endments of 1972 and the Water Quality
ntrol Act of 1973, became effective on June
1973. According to the Colorado Depart-
nt of Health (1974:5):

(1) State waters designated class B_1 or B_2
waters suitable or to become suitable for
purposes for which raw water is custom-
ly used, except primary contact recreation,
h as swimming and water skiing.

(2) Water in class B_1 exhibits or is to
ibit the following characteristics:

a. Bacteriological concentrations do not exceed a geometric mean of 10,000 total coliform groups or 1000 fecal coliform groups per 100 milliliters based on a minimum of not less than five samples obtained during separate 24-hour periods for any 30-day period, nor do 10 percent of the fecal coliform samples exceed 2000 groups per 100 milliliters during any 30-day period.

b. The dissolved oxygen concentration is not less than 6 milligrams per liter.

c. A pH rating of not more than 9.0 nor less than 6.0 units.

d. Temperature maintains a normal pattern of diurnal and seasonal fluctuations and does not change abruptly. No warming discharge is permitted in the hypoliminion of lakes. Temperature is not increased above 68°F by any means other than natural means, nor is temperature increased in streams and in the epiliminion of lakes or reservoirs more than 2°F by any discharge.

e. Wastes of other than natural origin does (sic) not cause the turbidity of the water to be increased by more than ten Jackson Units or its equivalent.

RESULTS AND DISCUSSION

Water Quality of the Area

Between July, 1974 and July, 1975, 340 water samples were collected within the study area. Bacterial counts for the fecal coliforms ranged from less than one organism per 100 milliliters to 274 organisms per 100 milliliters; the fecal streptococci concentrations ranged from less than one organism per 100 milliliters to a count in excess of 3000 organisms per 100 milliliters (see Tables 1, 2, and 3).

Geometric means for the fecal coliform concentrations at the lower sampling station (which are the indicators of pollution including recreation) never exceeded 11.63 organisms/100 ml. for a thirty-day period in which at least five samples were collected (see August, 1974, Table 2). Turbidities were quite low (between 2 and 25 FTU's), and dissolved-oxygen concentrations ranged from 8 ppm. during the spring snowmelt to 11 ppm. during the rest of the year. Nitrate concentrations were non-existent in the waters of the study area.

Thus, even with the heavy levels of recreational use in the area, the streams and lakes considered in this study are of extremely high quality, far exceeding the requirements for class B_1 waters (see Research Design and Methods). In fact, the fecal coliform concentrations, turbidities, and dissolved-oxygen concentrations also meet the requirements for class A_1 and A_2 waters (primary body-contact waters), but for these classes, the State of Colorado has also stated that:

> In addition, the fecal streptococcus count does not exceed an average of 20 per 100 milliliters based upon an average of five consecutive samples within a 30-day period. (Colorado Dept. of Health, 1974:4)

The results of the present study indicate that this requirement for class A_1 and A_2 water is not being met by the lakes and streams of the Cache la Poudre River watershed.

The fact that the waters of the study area are "pristine" but not of bathing and drinking-water quality is of importance since some

Table 1. Maximum, minimum, average counts and standard deviations of fecal coliforms/100 ml., 1974-1975.

Campground	Above				Below			
	$\bar{X}$	Min.	Max.	S	$\bar{X}$	Min.	Max.	S
Stove Prairie	8.44	1	45	17.64	9.40	1	46	12.24
Dutch George	5.60	1	29	7.22	4.96	1	39	8.77
Mountain Park	15.44	1	244	47.90	16.84	1	274	53.62
Fish Creek	4.08	1	13	4.22	6.80	1	37	9.56
Tom Bennett	2.40	1	11	2.49	3.16	1	22	5.96
North Poudre	2.41	1	12	2.85	1.41	1	4	0.85
Browns Lake	2.00	1	8	2.14	1.50	1	5	1.24
Comanche Lake	5.79	1	64	16.16	1.36	1	4	0.89

Table 2. Geometric means for fecal coliform bacterial counts at the lower sampling station of each campground.

Campground	1974				1975				
	July	Aug.	Sept.	Oct.	Dec.	Apr.	May	June	July
Stove Prairie	7.4	6.5	23.6	1.0	1.0	1.0	1.3	6.9	4.0
Dutch George	6.1	2.3	18.7	1.0	1.0	1.0	1.4	2.0	1.0
Mountain Park	12.9	3.8	20.2	1.0	1.0	1.0	1.2	1.6	1.0
Fish Creek	10.1	11.6	3.0	1.0	1.0	1.0	1.0	1.0	1.0
Tom Bennett	2.4	2.8	9.4	1.0	1.0	1.0	1.0	1.0	1.0
North Poudre	1.3	1.6	1.4	1.0	1.0	1.0	1.0	1.7	1.0
Browns Lake	1.0	2.0	2.2	1.0	--	--	--	1.0	1.0
Comanche Lake	1.0	2.0	1.7	1.0	--	--	--	1.0	1.0

Table 3. Maximum, minimum, average counts and standard deviations of fecal streptococci/100 ml., 1974-1975.

Campground	Above				Below			
	$\bar{X}$	Min.	Max.	S	$\bar{X}$	Min.	Max.	S
Stove Prairie	56.12	1*	249	63.72	49.40	1	160	38.36
Dutch George	45.40	1	158	39.74	40.56	1	149	36.31
Mountain Park	59.12	1	236	62.77	50.36	1	143	45.88
Fish Creek	41.68	1	198	49.34	68.32	1	300	89.40
Tom Bennett	18.84	1	167	37.75	23.84	1	203	43.64
North Poudre	25.88	1	67	21.97	37.29	1	116	39.34
Browns Lake	44.29	1	400	142.50	5.21	1	25	6.31
Comanche Lake	23.85	1	123**	34.82	13.54	1	61	18.77

*When results were less than one organism per 100 milliliters for fecal coliforms and/or fecal streptococci, the values were raised to one organism/100 ml. in order to utilize them mathematically. All minimum values shown above were actually "less than one organism/100 ml."

**The actual maximum value for this campground was "greater than 3000 organisms/100 ml.," but this skewed the data severely, and it is not considered in the above information.

ter-quality impacts of the different camper ncentrations, camper types, or campgrounds cessible by means of the different recreation tribution systems.

Stream Classification

The Cache la Poudre River watershed, luding the Little South Poudre and North udre sub-watersheds, upstream from the nt of water diversion for Greeley's water atment plant, has been classified as Quality ass B_1. This classification, adopted pursuant the Federal Water Pollution Control Act nendments of 1972 and the Water Quality ntrol Act of 1973, became effective on June 1973. According to the Colorado Depart- nt of Health (1974:5):

> (1) State waters designated class B_1 or B_2 waters suitable or to become suitable for purposes for which raw water is custom- ly used, except primary contact recreation, h as swimming and water skiing.
>
> (2) Water in class B_1 exhibits or is to ibit the following characteristics:
>
> a. Bacteriological concentrations do not exceed a geometric mean of 10,000 total coliform groups or 1000 fecal coliform groups per 100 milliliters based on a minimum of not less than five samples obtained during separate 24-hour periods for any 30-day period, nor do 10 percent of the fecal coliform samples exceed 2000 groups per 100 milliliters during any 30-day period.
>
> b. The dissolved oxygen concentration is not less than 6 milligrams per liter.
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Mountain Park	12.9	3.8	20.2	1.0	1.0	1.0	1.2	1.6	1.0
Fish Creek	10.1	11.6	3.0	1.0	1.0	1.0	1.0	1.0	1.0
Tom Bennett	2.4	2.8	9.4	1.0	1.0	1.0	1.0	1.0	1.0
North Poudre	1.3	1.6	1.4	1.0	1.0	1.0	1.0	1.7	1.0
Browns Lake	1.0	2.0	2.2	1.0	--	--	--	1.0	1.0
Comanche Lake	1.0	2.0	1.7	1.0	--	--	--	1.0	1.0

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	$\bar{X}$	Min.	Max.	S	$\bar{X}$	Min.	Max.	S
Stove Prairie	56.12	1*	249	63.72	49.40	1	160	38.36
Dutch George	45.40	1	158	39.74	40.56	1	149	36.31
Mountain Park	59.12	1	236	62.77	50.36	1	143	45.88
Fish Creek	41.68	1	198	49.34	68.32	1	300	89.40
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**The actual maximum value for this campground was "greater than 3000 organisms/100 ml.," but this skewed the data severely, and it is not considered in the above information.

ecreationists utilize the water of the streams r lakes for both direct body-contact recreation swimming, etc.) and domestic purposes. About 6 percent of the recreationists answering ne visitor survey said that they utilized the water bodies near campgrounds for drinking water, and 8 percent said that they used the water for bathing purposes. Given the bacerial-concentration levels present in the study rea, there is a potential health hazard for hese individuals. Moreover, there is a ealth hazard to non-recreationists who may tilize this water for domestic purposes without proper filtration and chlorination eforehand. Management actions to deal with his problem are, in part, incumbent upon the indings of the following study objectives.

Study Objectives

Objective 1: To determine if bacterial densities increase in water as recreational-user (camper) concentrations increase in nearby campgrounds.

A particular concern of those individuals harged with providing water for domestic use s that increases in the number of recreationists sing a domestic-water-supply watershed may ause an inordinate amount of pollution in the treams and lakes of that watershed. Personnel at the Fort Collins Water Treatment Plant ave verbalized this concern for the Cache la Poudre River watershed. Conversations with other individuals responsible for municipal water supplies have revealed that this is a concern of other areas along the Colorado Front Range. Moreover, recreation managers of Roosevelt National Forest and elsewhere ave expressed a concern for the health of recreationists who utilize lands and bodies of water within the national forest system. Thus, one of the objectives of this study is o determine if there is a trend toward higher bacterial counts in water with increasing evels of recreational-user concentrations n campgrounds.

Seasonal Variation in Bacterial Densities

In an analysis of seasonal variations in bacterial counts, it initially appears that there s a correlation between bacterial numbers and camper concentrations. There are generally low bacterial numbers during the winter months when recreational use is also at a minimum, and there is a rise in bacterial densities during the spring and summer months when recreational use is at a maximum. However, one is not justified in thinking that this is a significant relationship, since many variables interact in determining the bacterial concentrations present at any one time. In the winter, bacterial counts are low, because such influencing factors as water temperature and streamflow are also low. Higher bacterial densities in the spring and summer may be attributable to rising water temperatures which increase bacterial activity, and to rising streamflows and rainfall which wash feces and other debris from along the banks of the water bodies. Spring and summer is also the time when general use of the watershed begins to increase, and recreational use is only one aspect of this general land use. Thus, the problem is to distinguish between the bacterial-density increases that are due to recreational use of campgrounds and those bacterial increases that are due to other factors such as livestock grazing, etc. The use of upper and lower sampling stations at each campground should serve to accomplish the separation of recreation from other operant factors influencing bacterial increases.

Increases in Bacterial Density vs. Increases in Camper Use

Table 4 provides percentage values for the number of observations in which bacterial counts at the lower sampling station exceeded the bacterial counts at the upper sampling station for each of the camper-concentration levels considered in this study. These data are valuable both in indicating the actual pollution being contributed by recreationists, and in determining if bacterial densities increase as camper use increases.

The information in Table 4 does not provide conclusive evidence that bacterial-density increases occur concomitantly with user-concentration increases. Stove Prairie Landing and Fish Creek Campgrounds do exhibit percentage increases for the fecal coliforms as camper concentrations proceed from low to moderate to high levels, and Mountain Park, Tom Bennett and, to an extent, North Fork Poudre Campgrounds show

Table 4. Percentage values for the number of observations in which bacterial counts at the lower sampling station of each campground exceeded the bacterial counts at the upper sampling station vs. camper-concentration levels.

Campground	Low User Concentration	Moderate User Concentration	High User Concentration
Fecal coliforms (percentages):			
Stove Prairie	12	36	50
Dutch George	16	22	0
Mountain Park	11	55	40
Fish Creek	22	67	72
Tom Bennett	36	43	28
North Poudre	36	0	33
Browns Lake	16	0	0
Comanche Lake	16	0	0
Fecal streptococci (percentages):			
Stove Prairie	38	36	33
Dutch George	62	11	0
Mountain Park	11	27	60
Fish Creek	89	44	86
Tom Bennett	36	43	57
North Poudre	50	67	67
Browns Lake	50	0	0
Comanche Lake	33	16	66

the same progression for tests of fecal streptococci. However, maximum increases in bacterial densities were not always obtained during times of high camper concentrations; rather, maximum increases in bacterial counts occurred most often when there were only moderate or low concentrations of campers in the campgrounds. Thirty-eight percent of the time, highest bacterial-count increases occurred during moderate-use periods (4-7 campers/acre), and 37 percent of the highest bacterial-count increases were obtained during low-use periods (0-3 campers/acre). Only 25 percent of the maximum bacterial-density increases were obtained during high-use periods (more than 7 campers/acre). Thus, the results of this study indicate that there is a trend toward an inverse relationship between camper concentrations and increases in bacterial counts.

However, statistical analysis shows that there is no significant difference between the bacterial increases obtained during high recreational-use periods and the bacterial increases that may occur during either low or moderate recreational-use periods (X^2 for fecal coliforms was 4.34 and the X^2 for fecal streptococci was 6.61, the alpha level in both cases = .05). The resulting lambda correlation coefficients also indicate that little more than chance association exists between camper-concentration levels and differences in bacterial increases. For the fecal coliforms, lambda = .04, and for the fecal streptococci, lambda = .05. Simply summarized, there is no indication that increased concentrations of campers lead to increased pollution as measured by fecal coliform and fecal streptococci bacteria.

Actual Numbers of Campers vs. Bacterial Increases

Besides looking at camper concentration (number of campers/acre of campground), it is also possible to consider actual number of campers and their correlation with water-quality impact. Winter observations are excluded from this analysis since both numbers of campers and bacterial variations during this time are almost always zero.

During the sampling period, it was found that twenty-four increases in fecal coliform concentrations, ranging from an increase of 1 to 17 FC/100 milliliters, occurred when the actual number of campers present in any one campground exceeded the mean number of campers for that campground. Twenty-three increases in fecal coliform concentrations, ranging from an increase of 1 to 30 FC/100 milliliters, occurred when the actual number of campers present in the campground was less than the mean number of campers for that campground. For the fecal streptococci bacteria, twenty-seven increases in bacterial counts (range 1-294 FS/100 ml.) were obtained when the actual number of campers present in the campground exceeded the mean number of campers for that campground. Thirty-two increases in fecal streptococci densities (range 1-83 FS/100 ml.) occurred when the actual number of campers present in the campground was less than the mean number of campers for that campground.

This information indicates that there is no significant trend toward higher bacterial increases with higher numbers of campers. The highest value for an increase in fecal streptococci, 294 FS/100 ml., did occur when the actual number of campers present in the campground exceeded the average number of campers present, but this value occurred only once. The next highest increase for this category (actual number of campers exceeding the mean number of campers) was 96 FS/100 ml. Further, this increase of 294 FS/100 ml. was obtained at Fish Creek Campground on a day when the Pingree Park precipitation gage recorded .17 inches of rain (CSU Watershed Dept., unpublished data). This makes the interpretation somewhat more difficult since the rainfall probably had more influence in causing the rise in fecal streptococci than did the sheer numbers of campers.

Weekends vs. Weekdays

In yet another attempt to get at the problem of user concentration levels and water quality impact, a sampling scheme was designed to compare the water quality impact of recreationists on weekends and on weekdays. This was carried out during the summer of 1974. Greatest utilization of campgrounds in the study area occurs on weekends. It was found that the average number of people present in a given campground on weekends was thirty, while during the rest of the week the average number of individuals present in a campground was only fourteen. If higher bacterial concentrations occur due to intensive recreational use, then these elevated bacterial densities should be obtained on weekend sampling days. Table 5 presents data obtained for the weekend vs. weekday sampling routine.

In general, Table 5 indicates that there may be a slight trend toward more occurrences of bacterial increases on weekends than on weekdays for the fecal streptococci, but the average magnitudes of the bacterial increases indicate that actual increases in weekday fecal streptococci counts are almost twice the actual increases in weekend fecal streptococci counts. Thus, although there may be more instances of fecal streptococci rises on weekends, these increases are generally not as large (in actual fecal streptococci/100 ml.) as the increases that occur during the rest of the week.

The comparison of weekend vs. weekday fecal coliform rises also fails to provide evidence of a significant trend toward bacterial rises with high recreational-use periods. The fecal coliforms exhibited more instances of increases in bacterial counts during the weekdays, but the greatest average increase in fecal coliforms/100 ml. was obtained on weekends. However, the difference in weekend mean fecal coliform counts and weekday mean fecal coliform counts is less significant than that found for the fecal streptococci (see Table 5).

The sample size for the weekend vs. weekday comparison was not large enough to allow statistical analysis of the difference between bacterial-density increases on weekends and bacterial-density increases on weekdays. The expected frequencies usually fell below a value of five which would disallow the test of Chi squares (Freeman, 1965). However, the results given in Table 5 indicate that user concentrations are probably not significantly related to increases in bacterial densities.

Table 5. Percentage of observations in which bacterial counts at the lower sampling station exceeded the counts at the upper sampling station for weekends and weekdays.

Campground	Fecal Coliforms		Fecal Streptococci	
	Weekday	Weekend	Weekday	Weekend
Stove Prairie	16	25	16	33
Dutch George	16	0	17	33
Mountain Park	25	25	8	8
Fish Creek	42	17	42	25
Tom Bennett	33	25	25	45
North Poudre	9	0	36	27
Browns Lake	0	10	20	11
Comanche Lake	0	11	10	20
Mean increase in organisms	6.0/100 ml.	8.2/100 ml.	32.1/100 ml.	18.8/100 ml.

Discussion of Objective 1

The results of Objective 1 indicate that: (1) campers are contributing to the pollution of the watershed--however, their contribution by itself is insignificant when compared to existing water quality standards; and (2) there is no significant correlation between increasing camper concentrations and increasing levels of adverse water-quality impact. Seventy-five percent of the maximum bacterial-density increases occurred when only low camper concentrations (0-3 campers/acre) or moderate camper concentrations (4-7 campers/acre) were present in the campgrounds. High camper-concentration periods (more than 7 campers/acre) only exhibited 25 percent of the maximum bacterial-count increases observed during the study period. A comparison of actual numbers of campers to increases in bacterial densities and a comparison of weekday vs. weekend water-quality impact failed to provide any more conclusive proof of a positive relationship between high numbers of campers and consistent increases in bacterial water pollution.

There may be a number of reasons for these surprising results. One possible explanation is that during periods when there are few campers present in the campgrounds, the individual may not feel compelled to exercise any great amount of care in his actions. Peer group pressure may be functioning at a minimum, and the individual may dispose of wastes, etc., with little concern about reprisals. Such behavior could lead to greater water pollution during lower use periods. (Additional information regarding camper attitudes and behavior will be given in the following sections.)

Rainfall may be another factor that influences the number of bacterial increases observed during periods of minimal recreational use. As a general rule, few campers were present in campgrounds on rainy days, but it is during these times that surface flushing washes bacteria into the streams and lakes. A head count of campers present in campgrounds during rainy periods may derive relatively low numbers, but samples of the nearby water may show substantial increases in bacterial numbers occurring between the upper and lower sampling stations. Test results indicate that this situation did not take place consistently during the study period, but it was observed frequently enough to make the above theory, in part, a possible explanation of bacterial increases occurring during relatively low-use periods. In the final analysis, a number of social and environmental factors probably interact to produce the results observed. What is important is that higher concentrations of users are not creating higher concentrations of pollution.

Objective 2: To determine if there is a significant difference between the water-quality impact imparted by motorized campers and the water-quality impact imparted by backpack campers.

The present study was designed to compare the water-quality impacts of two types of campers: motorized campers and backpack campers. As previously discussed, motorized campers and backpack campers are not generally utilizing the same campgrounds. Thus, it is assumed that determination of any adverse water-quality impact occurring in a given campground can be related to the type of camper utilizing that campground.

A comparison of water-quality impacts imparted by backpackers and motorized campers showed that more instances and greater amounts of water pollution occur in campgrounds utilized by motorized campers than in campgrounds utilized by backpack campers. In general, 35 percent of the total water-quality observations made in motorized-camper campgrounds showed increases in fecal coliform bacteria at the lower sampling stations. The increases ranged from 1 to 30 FC/100 ml.; the mean increase in fecal coliform bacteria was 4.8 FC/100 ml. Eleven percent of the total water samples taken at backpack-camper campgrounds exhibited an increase in fecal coliform bacteria at the lower sampling stations. These increases were never more than 2 FC/100 ml. Forty-six percent of the water-quality observations at motorized-camper campgrounds showed an increase in fecal streptococci concentrations at the lower sampling stations. These increases ranged from 1 to 294 FS/100 ml. with a mean increase of 47.5 FS/100 ml. Twenty-six percent of the water-quality observations at the backpack-camper campgrounds derived increases in fecal streptococci bacteria; the increases ranged from 1-10 FS/100 ml., with a mean increase of 4.1 FS/100 ml.

Table 6 provides a comparison of bacterial increases as a percentage of total observations/campground for each of the campgrounds included in this study. The backpacker campgrounds (Browns and Comanche Lakes) do not exhibit a significant amount of adverse change in water-quality levels (as measured by fecal coliform bacteria) between the upper and lower sampling stations. In fact, considering the two campgrounds together, the results show that 75 percent of the total observations made during the study period exhibited no difference at all between the fecal coliform concentrations obtained at the upper sampling stations and the fecal coliform concentrations found at the lower sampling stations.

Results for the motorized-camper campgrounds indicate that somewhat more impact (increases in FC/100 ml.) is imparted by recreational utilization of these campgrounds, especially Fish Creek Campground. Almost half of the water-quality observations made at Fish Creek Campground showed increases in fecal coliform concentrations at the lower sampling station. Mountain Park and Dutch George Flats Campgrounds exhibit mean increases in FC/100 ml. that are only a few points below the mean increase in FC/100 ml.

Table 6. Bacterial increases (as a percentage of total observations/campground), ranges of bacterial increases and mean bacterial increases for each campground included in this study.

	FC	Range	Mean	FS	Range	Mean
Campground	%	(FC/100 ml.)		%	(FS/100 ml.)	
Stove Prairie	36	1-15	4.2	40	3-76	28.2
Dutch George	16	2-17	6.0	36	2-25	9.8
Mountain Park	36	1-30	5.6	28	2-40	14.1
Fish Creek	48	1-28	7.9	72	1-294	41.4
Tom Bennett	36	1-11	3.3	44	1-36	9.7
North Poudre	35	1-2	1.4	59	1-60	23.3
Browns Lake	14	1-2	1.5	21	1-5	3.0
Comanche Lake	7	1	1.0	36	1-10	4.6

obtained at Fish Creek Campground; however, the number of instances in which such increases were observed at the former two campgrounds is significantly fewer than the number of increases observed at Fish Creek Campground. Fish Creek Campground is a special case and more will be said about this campground later; for now, it is excluded from the analysis of differences between the fecal-coliform changes found in backpacker campgrounds and the fecal-coliform changes found in motorized-camper campgrounds.

However, even with the influence of Fish Creek Campground omitted, there is a statistically significant difference between the fecal-coliform variations associated with backpack campers and the fecal-coliform variations associated with motorized campers ($\chi^2 = 15.47$, $\alpha = .01$). The association is evident for the backpack campers and the type of fecal coliform variation observed in campgrounds utilized by backpackers. From the data one can predict that little or no significant effect on water-quality levels, as measured by fecal coliform bacteria, will occur in backpacker campgrounds. However, it appears that it will not be so easy to predict the impact of motorized campers on fecal coliform concentrations. With the water-quality observations of Fish Creek Campground discounted, about one-third (31%) of the water-quality observations made in motorized-camper campgrounds showed an increase in fecal coliform concentrations at the lower sampling stations; another one-third (34%) of the water-quality observations showed a decrease in FC/100 ml. between the upper and lower sampling stations; and the remaining one-third (35%) of the water-quality observations showed no change in FC/100 ml. between the upper and lower sampling stations of motorized-camper campgrounds. Thus, although there were higher amounts and significantly more instances of an increase in FC/100 ml. at the lower sampling stations of motorized-camper campgrounds than at the lower sampling stations of backpacker campgrounds, these increases were not consistent occurrences. There appears to be an equal likelihood of fecal-coliform concentrations increasing, decreasing or remaining unchanged between the upper and lower sampling stations of motorized-camper campgrounds.

For the fecal streptococci, there also is a significant difference between the water-quality impact found at motorized-camper campgrounds and the water-quality impact found in backpack-camper campgrounds. Th motorized-camper campgrounds generally showed higher percentages of an increase in FS/100 ml. and significantly higher mean increases in fecal streptococci concentratio at the lower sampling station. This is particularly the case for Stove Prairie Landing, North Fork Poudre and Fish Creek Campgrounds. Even with the influence of these three campgrounds omitted from the analysi there is a statistically significant difference between the water-quality impact imparted b motorized campers and the water-quality impact imparted by backpack campers ($\chi^2 = 11.9$, $\alpha = .05$). One may expect only infreque increases in fecal streptococci concentratio in campgrounds utilized by backpack camper However, in motorized-camper campground one can expect to find significantly more cases of an increase in fecal streptococci concentrations at the lower sampling station and the magnitude of these increases in FS/100 ml. will be much higher than those increases found in backpack-camper campgrounds.

Discussion of Objective 2

The results shown above are somewhat surprising considering the fact that all but one motorized-camper campground are provided with toilet facilities, and many of the motorized-camper vehicles have self-contai toilets. (The visitor survey indicates that 3 percent of the motorized campers utilizing campgrounds in the study area had self-contained toilets in their vehicles.) Only one backpack-camper campground has toilet facilities available, and these receive minim use since they are in a fairly bad state of disrepair. It would be expected that water-quality impact would be more defined in bac packer campgrounds than was actually observed; the lack of proper toilet facilities would be expected to result in higher inciden of bacterial-count increases in nearby water bodies. Moreover, given the presence of toilet facilities in the motorized-camper campgrounds, one would expect to observe fewer bacterial-count rises in the waters near these campgrounds than were actually found.

One conclusion that may be drawn from these results is that the motorized campers may not always be using the toilet facilities provided at the campgrounds. The backpackers, if they are not utilizing what facilities are provided to them, must be exercising more care in eliminating their wastes. Some substantiation for this hypothesis comes from various field observations. The authors noted several instances in which wastes from camper-trailers were being discharged onto the ground in motorized-camper campgrounds.

Further insight is gained from the visitor survey: 19 percent of the motorized campers answering the survey said that they dumped their wastes onto the ground or onto the road, the latter action was also witnessed by the authors. Moreover, an individual interviewed at Dutch George Flats Campground said that he had seen one camper-trailer dump its toilet holding-tank directly into the Cache la Poudre River. Similar incidents have been recorded by national forest personnel at the campgrounds. Dumping of wastes into the river is possible at Dutch George Flats Campground since no barricades are present in the campground to prevent such an action. This behavior was not witnessed firsthand by the authors.

The above is not meant to indicate that all or even a majority of motorized campers are engaging in pollution practices. Most of the motorized campers observed in the campgrounds were relatively careful about their actions and were appreciative of the campground. The simple fact is that more polluting behavior was found to be associated with motorized campers. That a difference in attitudes and behavior may exist between motorized campers and backpack campers is evidenced by answers to questions in the visitor survey and firsthand field observations. Moreover, these attitudes and behavior are reflected in the differences in water-quality impact between motorized campers and backpack campers. Support for this position is provided by Catton (1969) and Tocher (date unknown) who have found in their research that car campers are usually less preservation oriented than those who prefer back-country camping (backpackers).

Objective 3: To determine if there are significant differences between the water-quality impacts occurring in campgrounds accessible by means of paved roads, unpaved roads and foot paths.

From Tables 1 and 2 it is evident that a certain amount of bacterial water pollution can be attributed to recreational utilization of the Cache la Poudre River watershed. Although this study found that increases in bacterial pollution are not necessarily associated with increases in camper concentrations, it has been found that differences in camper types (backpack campers and motorized campers) and differences in the attitudes and behavior of these campers influence the level of water-quality impact to be observed. However, it can be seen from Table 6 that inordinate amounts of bacterial water pollution are not always the rule in motorized-camper campgrounds. The following analysis and discussion is a further attempt to differentiate campgrounds according to the amounts of adverse water-quality impact observed. The aim is to find out what types of recreation distribution system allows access to campgrounds where a significant amount of bacterial water pollution is being observed and to determine if all campgrounds accessible by that type of distribution system are exhibiting the same amounts of bacterial increases.

As explained previously, paved roads, unpaved roads, and foot paths were the types of recreation distribution systems considered in this study. Each campground within the study area is made accessible by means of one of these three recreation distribution systems. Table 7 provides data on mean bacterial increases and the percentage of water-quality observations showing an increase in bacterial counts at the lower sampling stations of campgrounds served by paved roads, unpaved roads, and foot paths.

For the fecal coliform bacteria there is no significant difference between the average bacterial increases found at unpaved-road campgrounds and the average bacterial increase found at paved-road campgrounds, but the number of instances in which a bacterial increase was observed at unpaved-road campgrounds (42%) is considerably more than were found at paved-road campgrounds (28%). Only

Table 7. Type of recreation distribution system vs. percentage of water-quality observations exhibiting an increase in bacterial counts at the lower sampling stations and average values for these increases.

	% Increase in FC/100 ml.	Mean Increase	% Increase in FS/100 ml.	Mean Increase
Paved Road	28	5.14	35	18.5
Unpaved Road	42	5.20	58	28.8
Foot Path	11	1.33	29	4.0

11 percent of the water-quality observations made at foot-path campgrounds resulted in increases in fecal coliform concentrations, and the mean increase was much lower than the mean increase in FC/100 ml. found at either the paved-road campgrounds or the unpaved-road campgrounds. That a difference exists between the levels of water pollution (increases in FC/100 ml.) found at paved-road, unpaved-road, and foot-path campgrounds is statistically significant at the 99 percent confidence level ($\chi^2 = 19.24$).

For the fecal streptococci, the unpaved-road campgrounds again showed the greatest number and the greatest amount of bacterial increases. The foot-path campgrounds showed the least water-quality impact, and the paved-road campgrounds fell between these two extremes. Again, there is a significant difference between the bacterial increases (FS/100 ml.) observed at the campgrounds served by paved roads, unpaved roads and foot paths ($\chi^2 = 18.46$, $\alpha = .01$).

Discussion of Objective 3

There is a significant difference between the water-quality impacts (bacterial increases) observed at campgrounds accessible by means of the different recreational distribution systems. The foot-path campgrounds can be expected to show the least number of increases in bacterial counts, and these increases will be much smaller than those to be found in the campgrounds accessible by roads. The paved-road campgrounds will show lesser instances of an increase in FC/100 ml. than unpaved-road campgrounds, but the increases that do occur will usually be about the same as increases found at unpaved-road campgrounds. More than half of the time, unpaved-road campgrounds will show an increase in FS/100 ml., and these increases will be much greater than those to be found in either the paved-road campground or the foot-path campgrounds.

However, in comparing the campgrounds of the study area, it should be pointed out that the dilution factors at the foot-path campgrounds and at the paved-road campgrounds are probably such that lesser bacterial concentrations will be observed in these areas than in campgrounds served by unpaved roads For instance, the main stem of the Cache la Poudre River, along which the paved-road campgrounds are located, has a streamflow approximately five times the streamflow of the Little South Fork along which are located the unpaved-road campgrounds, Tom Bennett and Fish Creek Campgrounds. One may expe that the dilution factor working in the main stem of the Cache la Poudre River will obtai lower bacterial concentrations than will be found in the Little South Fork. This may account for much of the difference in the bacterial-count increases observed at unpaved-road campgrounds and at paved-road campgrounds.

Special Study Findings

Fish Creek Campground

A comparison of Tom Bennett and Fish Creek Campgrounds, both unpaved-road campgrounds and both located along the Littl South Fork with no significant difference in streamflow between campgrounds, shows tha Fish Creek Campground consistently shows more and higher instances of increases in bacterial concentrations. Fish Creek exhibited increases in fecal coliform bacteria at the lower sampling station 48 percent of the time (increases ranged from 1-28 FC/100 ml.) and showed increases in fecal streptococci bacteria 72 percent of the time (increases ranged from 1-294 FS/100 ml.). At Tom Bennett Campground, increases in fecal coliform bacteria were observed 36 percent of the time (increases ranged from 1-11 FC/100 ml.), and increases in fecal streptococci bacteria were found 44 percent of the time (increases ranged from 1-36 FS/100 ml.). Thus, a good deal of the water quality impact defined in campgrounds served by unpaved roads was the result of monitoring water-quality levels at just Fish Creek Campground.

Table 6 shows that North Fork Poudre Campground also contributed substantially to the incidence of an increase in fecal streptococci concentrations, but there seems to be no explicable reason for this campground to exhibit any more water pollution than does Tom Bennett Campground. North Fork Poudre and Tom Bennett Campgrounds do not differ significantly in their characteristics: both of these campgrounds have conveniently-located toilet facilities, trash cans, etc.; both of these areas are served by an unpaved-road system; and both campgrounds receive about the same amount of recreational use by motorized campers. Possibly, streamflow is again a factor since the North Fork of the Cache la Poudre River at North Fork Poudre Campground is considerably smaller than the Little South Fork at Tom Bennett Campground. Lack of dilution may have caused the rather high levels of fecal streptococci concentrations found at North Fork Poudre Campground.

However, there are a number of possible reasons for Fish Creek Campground showing such significant amounts of water pollution. Fish Creek Campground is made up of a series of pullout camping spots along the banks of the Little South Fork of the Cache la Poudre River below Fish Creek Picnic Ground. This system of pullouts is not ideal since it serves to spread campers up and down the streambank. Further, it is quite a distance from some of these pullouts to available toilet facilities, and it is possible that campers utilizing campsites more distant from the toilets fail to visit these facilities but dispose of their wastes at more convenient spots instead, e.g., nearby trees, etc. Substantiation of this may come from the fact that many more bacterial increases were observed at this campground than at other "more intensely-managed" campgrounds.

In late July of 1975, Roosevelt National Forest personnel opened Fish Creek Picnic Ground, previously a day-use area, to tent camping in an effort to dissuade use of the nearby pullout campsites and to limit further resource damage in these pullouts. It remains to be proven, but this management action could also be important to water quality since it will serve to concentrate campers in an area where proper toilet facilities are readily available. It is important to note that in dealing with one type of carrying-capacity problem, vegetation trampling and soil compaction, another type of carrying-capacity problem may also be rectified or averted altogether.

Considering the previous discussion, it appears that recreation distribution systems are probably not useful analytical tools in predicting potential water-quality impact. With the influence of Fish Creek Campground removed from the analysis of fecal coliform increases and the influence of both Fish Creek and North Fork Poudre Campgrounds removed from the analysis of fecal streptococci increases, there is no significant difference between the water-quality impact to be observed at paved-road campgrounds and the water-quality impact to be observed at unpaved-road campgrounds. However, there still is a difference between the water-quality impact found at foot-path campgrounds and the water-quality impact found at campgrounds accessible by a road, but this seems to come full circle back to the differences in water-quality impact observed at backpack-camper campgrounds and the water-quality impact observed in motorized-camper campgrounds.

Thus, the only predictive use that recreation distribution systems may have concerns expectations of water-quality impact at foot-path campgrounds and at campgrounds accessible by means of some type of road; this is also related to camper types and their impact upon water-quality levels. For the motorized-camper campgrounds, served by a road, the most influential factor upon water-quality impact seems to be campground design.

The strung-out series of camping spots found at Fish Creek Campground caused the greatest water pollution found at motorized-camper campgrounds. If management actions recently taken diminish the impact found in this campground, then there is even more substantiation for the conclusion that campground design can have a major influence on user impact on water quality.

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Overall Statement

This study was designed to isolate and evaluate the water-quality impact of recreational use. The sample size and the number of campgrounds included helps add to the reliability and validity of this study, and the findings of the research should be a substantial contribution to the existing body of knowledge concerning recreation-related water pollution.

The findings of this study indicate that recreational use is not at present a significant cause of bacterial water pollution, and ancillary monitoring shows that turbidity and dissolved-oxygen concentrations are also unaffected by recreational use. Recreational opportunities may be provided near water bodies with a minimum of resource investment for toilet facilities, trash cans, log-barricaded parking spots, etc. This is important since it would allow maximum recreational opportunities while maintaining an acceptable degree of water quality.

General

Findings

1. The waters of the Cache la Poudre River watershed are of extremely high quality, but cases of water pollution do occur. The existing water-quality levels were found to be much better than the thresholds established for class B_1 waters for which the watershed is designated, yet the waters do not meet class A_1 or A_2 requirements and thus, are unacceptable for direct body-contact recreational use or domestic use without prior treatment.

2. Recreational users (campers) are contributing a certain amount of bacterial water pollution at all of the campsites studied, but these bacterial contributions were found neve to exceed or even come close to the threshold established for class B_1 waters. This fact must be emphasized and will be reiterated throughout the following discussion.

3. Campground characteristics, siting of toilet facilities and provision of log barricade to prohibit direct access to water bodies may influence to a certain degree the bacterial increases to be found in waters near campgrounds.

Conclusions

Although campers are contributing to the bacterial pollution of the Cache la Poudre River watershed, the amount contributed at each campground is insignificant in terms of established water quality standards and in relation to the potential bacterial contributio of other types of land use within the watershe This is an important finding since the study area receives heavy recreational use, but still, only small amounts of adverse water-quality impact are found to be directly associated with that utilization. This adds support to the findings of several other researchers (see Literature Review) who have concluded that recreational use is not at present a major cause of water pollution.

Recommendations

Contrary to what has been theorized by many recreation managers and water-supply managers, there is no need to be overly concerned with recreational use and its contributions to bacterial water pollution within the Cache la Poudre River watershed or probably within other watersheds similar to the study area (see Black et al., 1959; Johnson, 1962; Meiman and Leavesley, 1974 However, it would be wise to periodically monitor the campgrounds of the area to make sure that recreational use continues to impa only minimal amounts of bacterial pollution to the streams and lakes of the area. Even though there appears to be little cause for concern at present about the water-quality impact of recreational use, it is important that the reader study the findings of the three major objectives included in this research. These findings have definite management implications for present and future recreational use of wildland watersheds based upon the trends and characteristics of existing water users.

Objective 1

Findings

1. The results of this study indicate that there is no association between increasing levels of bacterial pollution and increasing levels of camper concentrations in campgrounds. Bacterial densities do not necessarily increase with increased camper concentrations.

2. There seems to be almost an inverse relationship between cases of bacterial-density increases and levels of campground utilization. Many bacterial-density increases found during this study were observed during periods when few campers were present in the campgrounds.

3. No matter how much bacterial water pollution was contributed by recreational use, the bacterial increases found never approached the thresholds for class B_1 waters.

Conclusions

1. The apparent trend toward more and higher bacterial-density increases during low-camper-use periods may be due, in part, to rainfall. Bad weather keeps many potential campers away, but surface runoff during or shortly after rainfall washes bacteria into the nearby water bodies (Morrison and Fair, 1966).

2. Another explanation for the fact that bacterial-count increases were found during low recreational-use periods is that campers possibly feel less compulsion to exercise care in their actions when few recreationists are present to take exception to careless behavior. During low-use periods, an inconsiderate camper may dispose of wastes on the ground, etc., without fear of reprisals from other campers who would be nearby during higher-use periods.

Recommendations

Based upon the above discussion, it is recommended that recreation managers strive to concentrate campers as much as possible to diminish the potential for careless or inconsiderate actions on the part of recreationists. This is obviously not an ideal suggestion from the standpoint of social carrying capacity, but as it concerns water quality, such an action seems justified. Moreover, the provision of readily-accessible toilet facilities and trash cans and the existence of log barricades will also help to minimize the cases of bacterial increases in water near campgrounds.

Objective 2

Findings

1. The results of this study indicate that there is a significant difference in the number of cases and the amounts of bacterial water pollution contributed by motorized campers and backpack campers.

2. More cases of bacterial pollution were found to be associated with recreational use by motorized campers than with recreational use by backpack campers.

3. Much higher bacterial increases were found in motorized-camper campgrounds than in backpack-camper campgrounds.

Conclusions

1. Motorized campers may not always be using the toilet facilities provided in campgrounds.

2. Backpack campers, while probably not using what toilet facilities are provided in backcountry campsites, must be exercising considerable care in disposing of wastes.

3. The differences between the water-quality impacts observed at motorized-camper campgrounds and water-quality impacts observed at backpacker campgrounds, answers to the visitor questionnaire, and field observations and conversations indicate that a difference in attitudes and behavior exists between

motorized campers and backpack campers.

Recommendations

Since the recreation manager may expect to find more cases and greater amounts of bacterial water pollution associated with motorized campers than with backpack campers, there is a need in motorized-camper campgrounds: (1) to construct log barricades where they are not now present to prevent vehicular approach to water bodies near campgrounds; (2) to insure that toilet facilities are easily accessible; and (3) most important of all, to embark on an educational effort possibly involving pamphlets, brochures or personal contact to acquaint the campers using motorized-camper campgrounds with the possible consequences of dumping the holding tanks of self-contained vehicles into the water or onto the ground, eliminating wastes in spots other than toilet facilities, etc. Moreover, this educational endeavor should be aimed at influencing the campers not to utilize the streams and lakes near the campgrounds for drinking or bathing water because of the potential health hazard.

Objective 3

Findings

1. Water-quality impact (bacterial increases) observed at footpath campgrounds were much less than that observed at campgrounds accessible by means of some type of road system. This gets back to the question of differences in water-quality impact imparted by motorized campers and backpack campers. The type of camper is probably much more influential than the recreation distribution system in determining the water-quality impact.

2. Differences in water-quality impact were found to exist between paved-road campgrounds and unpaved-road campgrounds, but these differences are not very pronounced once the influence of Fish Creek Campground (an unpaved-road campground) is removed.

3. Fish Creek Campground is a special case, and it was found that this campground was responsible for a great amount of the bacterial water pollution found at motorized-camper campgrounds. Fish Creek campgrou is a strung-out type of campground, and step taken by Roosevelt National Forest during th summer of 1975 to consolidate recreational use of this area into Fish Creek Picnic Grou (previously a day-use area only) may serve to diminish the bacterial contributions observed in the area of Fish Creek Campgroun

Conclusions

1. Use of recreational distribution systems as a management tool is probably not a meaningful endeavor here. Campground characteristics and camper types are probab much more influential in determining water-quality impact in a given campground.

2. A series of pulloff campsites (Fish Cree Campground) with toilet facilities only sited at some of the pulloffs is not an ideal situatio from the standpoint of water quality because it serves to spread campers up and down the banks of the stream increasing the potential for occurrences of water pollution.

Recommendations

Again, consolidation of campers appears to be the most appropriate recommendation from the standpoint of water quality. Provision of convenient toilet facilities and log barricades may help in some cases to dimini bacterial water pollution related to strung-out campgrounds, but the better practice is to provide proper facilities within a more compact campground. Further, a continuing water-quality monitoring effort should be directed at the newly-opened Fish Creek Picnic Ground to determine if this manageme action solves the water-quality "problem" observed during the study in the area of Fish Creek Campground. Even the bacterial-count increases found at Fish Creek Campground were not significant enough to exceed class B_1 water-quality standards.

Further Research

Even given the heavy recreation use in the Cache la Poudre watershed, water pollution due to recreation is presently insignificant. However, as the demand for and use o water recreation sites increase, there will eventually be a threshold level at which recreationists are significantly polluting watersheds. There is a definite need to predict these threshold levels in order to avoid human health hazards on the watersheds due to recreation. These investigators believe that the threshold levels can be found through research simulation techniques.

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